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Mathematical Modelling Competencies Mastery Among Secondary School Teachers

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Abstract
Mathematical modelling is a new topic introduced in the Malaysian mathematics form five syllabus. Therefore, it is important to explore teachers' ability in teaching mathematical modelling to produce effective learning. The knowledge about teachers' abilities can provide input on teachers' strengths and weaknesses in implementing interventions. The research aims to identify the mastery level of in-service teachers in mathematical modelling competencies. The survey research design was implemented using a 14-items mathematical modelling competency test. The combined sampling techniques consisting of cluster sampling, systematic sampling and simple random sampling were used to select respondents. 85 teachers who teach form three, form four or form five students from secondary schools in Selangor were selected. The data analysis process was carried out using SPSS 26.0 by performing descriptive analysis and inferential statistics. The mean scores were used to identify the mastery level, and the mean scores for five sub competencies were compared to determine the stage of the cycle process of mathematical modelling that the teachers mastered. The significant findings show that the secondary teachers had moderate mastery levels. The teachers were competent at the second stage of the mathematical modelling cycle process, which is formulating a mathematical model but lacked competence in the first stage, which is translating real-life models into mathematical models. Meanwhile, the one-way ANOVA result showed no difference between the mean scores of competency tests based on the form levels taught by mathematics teachers. This indicates that teachers have lack experience in solving mathematical modelling problems, so there is not much difference in their competency test scores Future research should identify teachers' mastery of other competencies, especially those involving problem-solving measures that can be implemented to explore in-depth the ability of teachers.
Keywords: Mathematical Modelling, Competency, Teacher, Secondary School, Mathematics.

Introduction
In Malaysia, Mathematical Modelling is a new topic introduced in the form five's Mathematics subject starting from 2021 (Curriculum Development Division, 2016). This topic is included in the form five syllabus according to the latest syllabus in the Kurikulum Standard Sekolah Menengah (KSSM). The implementation of KSSM is done in stages and the form five students in 2021 are the pilot students for the new syllabus. Based on the KSSM Mathematics

Curriculum and Assessment Standards Document for form four and form five students, one of the learning standards that students need to achieve is that students will able to explain the mathematical modelling cycle process, which starts from identifying and defining problems, making assumptions and identifying variables, applying mathematics to solve problems, verifying and interpreting solutions in the context of the problem, refining mathematical models, and finally reporting findings (Curriculum Development Division, 2018). These six levels in the mathematical modelling cycle process have competencies and sub competencies that can be mastered (Ferri, 2019; Hidayat & Iksan, 2018; Leong & Tan, 2020; Tan & Ang, 2016).

However, solving problems using these six mathematical modelling competencies is not an easy process. Research by Leong and Tan (2015) on school students as well as research by Hidayat and Iksan (2018); Dogan (2020) on prospective teachers found that there are some competencies in mathematical modelling that are difficult to master. As a new topic that is introduced in the Malaysian syllabus, the mastery level of teachers in mathematical modelling competencies is reasonable to identify. To test the teachers' competency mastery level, this research adapted the instrument of competency test that was published in combination done by Haines, Crouch, Davis, Houston, Neill and Fitzharris (Haines & Crouch, 2007). This competency test is able to identify teachers' mastery of mathematical modelling competencies in general based on their knowledge and ability to determine the correct answers without showing the calculation steps (Hidayat & Iksan, 2018).

Haines and Crouch (2003) research have tested this instrument on undergraduate students for non-teaching courses who are still new in mathematical modelling. The results of the research found that these students had difficulty in relating real problems with mathematical models and vice versa. They experience problems in the early stages of the mathematical modelling cycle process, especially in the part of translating the problem into the form of a mathematical model, rather than solving the problem after successfully developing the model. Students felt that they understood a given problem, even though in fact they had difficulty determining the knowledge and procedures that needed to be applied and the connections that needed to be made. In contrast, research by Hidayat and Iksan (2018) found that prospective teachers in Indonesia are efficient in simplifying assumptions and formulating mathematical statements, but have difficulty in making relationships and parsing graphical representations and then elaborating the answers in real situations. Therefore, research on in-service teachers may provide a different perspective.

The ability and mastery of a teacher is the backbone to form the skills and mastery of students. Teachers' mastery in mathematical modelling competencies is important to help students implement problem solving more systematically and well planned (Leong, 2013). Studies on teacher mastery can provide guidance to the authority for the ability and readiness of teachers and identify their strengths and weaknesses in mathematical modelling competencies. At the same time, they can plan intervention programs to improve teachers' mastery in mathematical modelling. Apart from that, the findings of this research can be the trigger for the idea to make further research on mathematical modelling, especially in Malaysia. As the topic of mathematical modelling is still unfamiliar in Malaysia, not much research involving teachers and students have been implemented. Most overseas studies that are related to the mastery of mathematical modelling competencies are conducted on school students, college students and prospective teachers. There are still limited studies involving in-service teachers in identifying the mastery level of mathematical modelling competencies.

Therefore, the purpose of this research was to identify the extent to which secondary school mathematics teachers mastered mathematical modelling competencies. Specifically, the objectives of this research were to;

i. identify the mastery level of mathematical modelling competencies among secondary school mathematics teachers.

ii. identify the mastery of mathematics modelling competencies among mathematics teachers according to the form levels taught by the teachers in 2021

Hence, to answer the research questions, quantitative approach was chosen. The research design was survey research that used a mathematical modelling competency test. The research instrument was administered through Google Form. The survey only involved 85 secondary school mathematics teachers in the state of Selangor. After the data were collected, the teachers' answers were analysed using Statistical Package for Social Science (SPSS) version 26.0. Thus, to identify teachers' mastery level of mathematical modelling competencies, descriptive analysis was performed by comparing the overall scores and also comparing the mean scores for five sub competencies. In addition, one-way analysis of variance (ANOVA) was also used to identify whether there is a difference in mathematical modelling competency based on forms taught by teachers. The next section of the article explains about the literature review which covers the theories and concepts of mathematical modelling competencies as well as previous studies related to mathematical modelling competencies in education. This is followed by a section that describes the research methodology and finally a section that discusses in detail the findings of the research as well as the implications and recommendations of future research.

Mathematical Modelling

Werner Blum was one of the earliest figures to introduce the concept of mathematical modelling (Ferri, 2013). Blum (1993) concludes that mathematical modelling is a process of constructing a mathematical model from a real problem situation or applying problem solving or relating a real situation problem to mathematics. Moreover, Ang (2015) states that mathematical modelling is a process of translating real reality problems into mathematical models and solving those problems. This definition is in line with a study by Haines and Crouch (2003) in constructing the mathematical modelling competency test which states that mathematical modelling is a cyclical process to abstract real-world problems, convert them into mathematical form, solve the problems and evaluate them through six cycles of mathematical modelling process. Therefore, mathematical modelling can be formulated as a problem-solving process of translating real-life situations into the form of mathematical models and solving them.

Moreover, the same definition is used and serves as a teacher's guide for the topic of Mathematical Modelling in form five textbook. Hence, an important element that needs to be known in mathematical modelling is the mathematical modelling cycle process. According to

Maaß (2006), the mathematical modelling process is not a linear or one-way process, instead it is a cyclical process involving several stages.

Mathematical Modelling Cycle Process

Overall, there are various forms of mathematical modelling cycle processes that can be identified (Maaß, 2006). However, basically the cycle has almost identical stages. The ideal and widely adopted mathematical modelling cycle by researchers is the one introduced by Blum (1996) (Maaß, 2006; Kaiser, 2007; Ferri, 2013) as represented by Maaß (2006) in Figure 1.1;

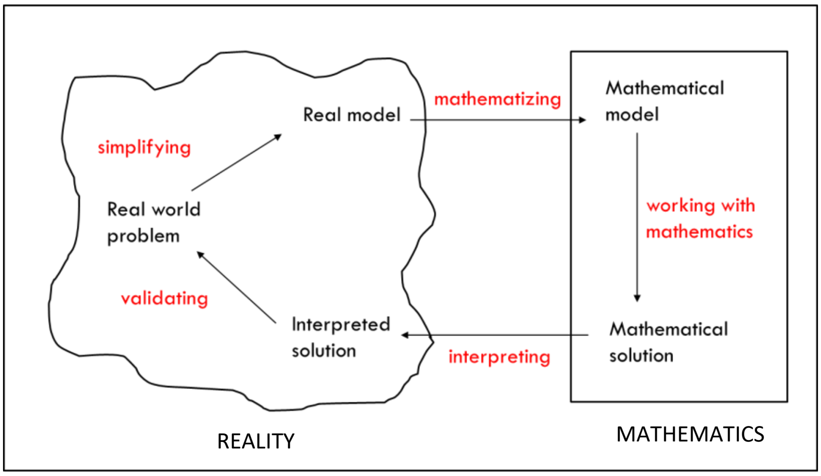

Figure 1.1 The modelling cycle process by Blum (1996, p.18) and represented by Maaß (2006)

Based on the description by Blum (1996), the modelling cycle process begins by looking at the problem from the context of real life. The real problem will go through the process of simplifying, structuring and idealizing that will produce a reality model. Next, this reality model is translated in the form of a mathematical model. The next step is to solve the problem using mathematical computational concepts. This solution needs to be interpreted in the form of a statement and then be verified. If the chosen solution or process does not match the original reality problem or is not proven suitable for solving the problem, then certain steps in the process or the whole process need to be repeated.

This mathematical modelling cycle process by Blum (1996) was adapted and improved by many researchers such as Ferri (2006); Kaiser - Messmer (1986); De Lange (1989); Galbraith (1989, 1995) (Maaß, 2006). The difference of the cyclical process between the researchers is in the number of stages, which are either six or seven stages and the sequence of stages after problem solving. However, the basics of the cyclical process are still the same as described by Blum, where the modelling cycle process begins with the real-life problem and ends with reporting the findings.

The mathematical modelling cycle process that was introduced in the KSSM Mathematics syllabus has a similar cycle. The cycle begins with real-life problems, then identifying and defining problems, followed by making assumptions and identifying variables, then applying mathematics to solve the problems, verifying and interpreting solutions in the context of the problem, refining models and lastly reporting findings (Curriculum Development Division, 2018). According to the syllabus, students need to know the cyclical process and should be able to solve a given problem by following the process. However, the real-life problems given are limited to questions involving linear functions, quadratic functions and exponential functions. Apart from the cyclical process of mathematical modelling, another concept that is closely related to the cyclical process is the competencies of mathematical modelling. In general, mathematical modelling competencies are skills at every stage in the mathematical modelling cycle process (Blum & Kaiser, 1997; Maaß, 2006).

Mathematical Modelling Competencies

Mathematical modelling competencies can be defined into many different meanings in general (Ang, 2015; Ferri, 2013; Haines & Crouch, 2001; Kaiser, 2007; Maaß, 2006). These differences in the definition and type of competency depend on the field covered by mathematical modelling. For this research, the explanation given covers the domain of pedagogy and the field of education. According to Maaß (2006), mathematical modelling competencies consist of the skills and ability to implement the mathematical modelling cycle process correctly and have the willingness to implement it. The understanding related to the skills and competencies in mathematical modelling is closely related to the process of the mathematical modelling cycle. Mathematical modelling competency is not only limited to transforming reality model to mathematical model, but also the willingness to solve the problems by implementing mathematics concepts through the process (Kaiser, 2007). This description has a similar definition to Jensen (2007) who states that mathematical modelling competency is a person's deep readiness in performing all the mathematical modelling processes on a given situation. Thus, mathematical modelling competency can be formulated as the ability or willingness of an individual to carry out the process of the mathematical modelling cycle in solving real-life problems.

The scope and terminology of these mathematical modelling competencies are detailed in the research of Blum and Kaiser (1997) by listing mathematical modelling competencies based on the six steps in the mathematical modelling cycle process (Maaß, 2006). The research also lists out the sub competencies which are detailed explanations to the mathematical modelling competencies. This step was followed by Haines and Crouch (2001) in constructing and categorizing competency test items based on eight mathematical modelling cycle processes. There are few differences in sub competencies than those stated by Blum and Kaiser (1997), yet the competencies that they cover are still the same.

Mastery of Mathematical Modelling Competencies

Mathematical modelling competency is not an easy skill to be mastered (Ang, 2012; Hidayat & Iksan, 2018). The mastery of each competency is different, based on individual prior knowledge (Ang, 2012; Leong & Tan, 2020). According to Haines and Crouch (2007) the difficulty that is often encountered by students is in translating real-life problems into mathematical models, and this problem is clearly faced by individuals who are new in mathematical modelling. Among the causal factors is due to the lack of basic knowledge in mathematical modelling and lack of exposure in solving problems involving mathematical modelling. However, the skills can be improved if the student could increase the knowledge in mathematical modelling and frequent exposure is given in solving mathematical modelling problems. This can be seen in a research done by Haines and Crouch (2007), through the comparison of the ability of the first-year undergraduate students who take mathematics modelling courses with the students who are in the second or subsequent years students.

For upper secondary students in Malaysia, Leong and Tan (2020) found that some groups of students are not proficient in making assumptions, calculations, mathematical reasoning, formulating mathematical models and interpreting solutions, while some groups are able to make assumptions, formulate mathematical models and do the calculations. Although they were not able to solve the questions accurately, they were able to implement each competency in the modelling cycle process. These findings are similar to previous studies of Leong and Tan (2015) using different mathematical modelling problems. The conclusion that can be made is that mathematical modelling competencies are not easy to develop among upper secondary students in Malaysia because students are accustomed to only completing simple mathematics exercises in the classroom (Leong & Tan, 2020).

The findings by Leong and Tan (2020) are in line with a research by Frejd and Ärlebäck (2011) on upper secondary students in Sweden. Students have difficulty simplifying assumptions related to real-life problems, explaining the goals of reality models and choosing the right mathematical model to solve the problem. They are proficient in formulating problems and determining variables, parameters and constants for mathematical models because they have been exposed to the skills of constructing mathematical models in their syllabus (Frejd & Ärlebäck, 2011). Thus, mastery in mathematical modelling competencies depends on students' prior knowledge that they have learned while in the classroom.

A research by Hidayat and Iksan (2018) on prospective teachers shows a different result. The results of the research found that prospective teachers have a moderate level of mastery in mathematical modelling competencies. Most prospective teachers are proficient in questions related to simplifying assumptions and formulating mathematical statements, but incompetent in questions that need to elaborate graphical representations and reconnecting solutions to real situational problems. The results of this research are different from the findings of studies by (Frejd and Ärlebäck, 2011). Hidayat and Iksan (2018) explain that factors such as mature age and strong mathematical background among prospective teachers are the reasons that ensure they have a good mathematical knowledge to answer mathematical modelling questions.

Nevertheless, the research by Haines and Crouch (2003) on undergraduate students for non-teaching courses and the research by Joo (2017) on three trainee secondary school teachers are in line with (Frejd and Ärlebäck, 2011). They experience problems in the early stages of the mathematical modelling cycle process where these teachers have difficulty relating real-life problems to mathematical models. This finding contradicts with the findings by Hidayat and Iksan (2018) although they use the same competency test instrument such as (Haines and Crouch, 2003). Various factors may influence teachers' mastery of mathematical modelling competencies and one of them is the lack of experience and exposure to solve the mathematical modelling questions (Ang, 2012). Further studies can be undertaken to examine the factors that influence teachers' mastery in mathematical modelling competencies. However, this research focused only on determining the mastery of competencies among in-service mathematics teachers. Because the respondents of this research are different from previous studies, the mastery level among in-service mathematics teachers in mathematical modelling competencies may bring a different perspective than secondary school students or prospective teachers.

Methodology

This quantitative research used a survey research design. This design was chosen because this research requires researchers to identify the mastery level of mathematical modelling competencies for many teachers and the data obtained can be used to determine the existence of relationships between variables and at the same time to test the objectives of the research (Glass & Hopkins, 2021; Nik Pa, 2016).

Population, Sampling and Location

The population of this research is mathematics teachers who teach in secondary schools in the state of Selangor. The respondents of the research consisted of 85 teachers who teach form three, form four, or form five students. The rationale for this selection is because most of the schools in Malaysia are in two-session and there is a high possibility for form three and form four teachers to teach form five students in the next coming years. Therefore, apart from the teachers who teach form five in 2021, teachers who teach form three and form four students are also taken into account to assess their mastery level in mathematical modelling competencies. This also coincides with the population characteristics described by Creswell and Creswell (2018), where the target population is a group or individual with similar characteristics that can be identified by the researcher.

To determine the research sample, a random sampling method by combining three sampling techniques was used. This sampling is suitable for use when the population is large and it is difficult for researchers to get the total number of teachers who teach form three, form four, or form five students accurately (Fraenkel et al., 2012). Cluster sampling technique is used in the first stage where mathematics teachers are grouped according to schools that produced a total of 234 schools. After that, a total of 46 schools were selected that represent almost 20 percent of the schools. In the second stage, the name of the selected school was determined by using systematic sampling. Next in the third stage, simple random sampling is used to select mathematics teachers who teach form three, form four or form five students. These selection methods are saving more time and cost rather than random selection according to the number of teachers (Fraenkel et al., 2012). The location of the research involves national secondary schools in the state of Selangor. Based on the list of schools in the state of Selangor that was obtained through the official website of the Selangor State Education Department, the number of secondary schools that have been identified is 234.

Instrumentation

This research used an instrument that was adapted from Haines et al (2003) which is a competency test in the form of multiple choice questions (Haines & Crouch, 2003). The original instrument contained 22 items but only 14 items were selected based on their suitability with the syllabus in Malaysia. The advantage of this competency test is that the respondents using a short time to answer the questions and the scores obtained can give a brief overview of the mastery level in mathematical modelling competencies without having to perform the entire mathematical modelling task (Haines & Crouch, 2003; Hidayat & Iksan, 2018). The questionnaire instrument of this research is divided into two parts, which are the demographic part to obtain the background of the participants and the mathematical modelling competency test. Each item in this competency test is in the form of a problem-solving question, where a brief problem statement or an incomplete problem statement is given at the beginning of the question. Then, there are five objective answers given after the question is posed. Each correct answer carries 2 marks, a partially correct answer carries 1 mark and a wrong answer carries 0 marks. Therefore, the highest score that could be obtained by the respondents was 28 marks.

These competencies were then sorted by category based on stages in the mathematical modelling cycle process and five sub competency categories were identified (Crouch & Haines, 2003; Lingefjärd, 2004; Hidayat & Iksan, 2018). The five sub competencies are understanding situations and simplifying assumptions (MMC1), formulating mathematical models (MMC2), determining variables (MMC3), formulating appropriate statements (MMC4), representing graphs to real situations and using mathematical concepts (MMC5). The MMC1 sub competency represents the first stage competency in the mathematical modelling cycle process, which is the competence to understand real problem situations and build models. While the sub competencies MMC2, MMC3, MMC4 and MMC5 represent the second stage competencies in the mathematical modelling cycle process, namely the competence to formulate mathematical models. Table 3.1 shows the details of the competencies and sub competencies involved, the codes and item numbers that represent the sub competencies.

Table 3.1 competency and sub competency categories in competency test

Code	Competency	Sub competency	Item number
MMC1	Understand real problem situations and build reality models	Make and simplify assumptions - determine the assumptions that are included and not included in the model	1,2,3
MMC2	Formulate mathematical models	Detail the problem statement so that it can be formulated into a mathematical model	4,5,6
MMC3	Formulate mathematical models	Specify variables, constants or parameters to include in the mathematical model	7, 8, 9
MMC4	Formulate mathematical models	Formulate appropriate mathematical statements (mathematical models)	10, 11, 12
MMC5	Formulate mathematical models	Form a graphical representation	13, 14

Validity and Reliability

A validation process was performed to identify whether the instrument used was in line with the field of research or otherwise (Hair et al. 2014). The instrument of this research was examined by a linguist for the purpose of instrument translation. For the purpose of content validity, the research instruments were reviewed by two experts with expertise in mathematics. The results of the feedback from experts are used to improve sentence structure and ensure that only items that are appropriate to the syllabus and the context of the questions in the Malaysian environment are used in the competency test (Nizam & Rosli, 2020).

A pilot study was conducted on 32 mathematics teachers from secondary schools outside the states of Selangor. The results of the reliability statistical test found that the value of Cronbach's alpha coefficient is 0.65. This value is less than the results obtained by Haines et al. (2003) on the competency test they constructed with a score of 0.88 and the research of

Hidayat et al (2021) with results of 0.87 for the overall Cronbach's alpha coefficient. However, this value still allows items to be accepted for use in the research (Taherdoost, 2018). Items need to be checked and improvised to increase the reliability.

Data Collection and Analysis

The mathematical modelling competency test was constructed online using Google Form. Then, the test was distributed to the respondent through a link that was generated by the platform. Vasantha and Harinarayana (2016) stated, Google Form is an application that can facilitate users to design and develop web-based survey questionnaires. An email containing a request letter to collect data and a link to the Google Form is sent to the selected school. In response, the school administrator then appointed the teachers as the respondents. The test link is then copied and given to the respondents through the medium of online applications such as WhatsApp and Telegram. After that, the respondents' answer was recorded in a spreadsheet application that linked to the Google Form.

Subsequently, the data was analyzed using SPSS 26.0 statistical software. To answer the first objective of the research, descriptive analysis was performed to determine the mean, median, mode and standard deviation of the overall score. Box plots and frequency tables for the five mastery level categories were constructed to clearly show teachers' mastery levels (Odili & Asuru, 2010). In addition, mean scores and standard deviations for the five sub competencies were determined to compare and assess teachers' mastery in mathematical modelling competencies (Hidayat & Iksan, 2018). Furthermore, to identify the relationships between the variables for the second objective, inferential analysis was used (Creswell & Creswell, 2018). Researchers used one-way analysis of variance (ANOVA) to identify whether the mastery level of mathematical modelling competency was influenced by the form level taught by teachers. Thus, the mastery of teachers who teach form five is compared with that of teachers who teach form four and form three students.

Result

Descriptive Analysis

The descriptive analysis of overall competency test scores was conducted to answer the first objective of the research which is to identify the mastery level of mathematics modelling competency among mathematics teachers. The results of the analysis found that the mean score of the respondents' overall score was 13.84 marks. The highest total score for this competency test is 28 marks, therefore the median score is 14. Overall, the average score obtained by the respondents is approaching the median score. Other than that, the score mode is 12 and the standard deviation of the score is 4.67. The standard deviation value of the score is small and this indicates that the score is more consistent due to less variability in the score (Allen et al., 2014). The highest score obtained by the respondents was 24 marks while the lowest score obtained was 5. Thus, the range of the score for the competency test was 19 and this value showed a large gap when compared to the full marks. Table 4.1 shows the details of the mean value, mode, standard deviation, range, maximum value and minimum value of the marks obtained by the respondents.

Table 4.1 Descriptive analysis of overall competency test scores

	Statistic	Total
Score	Respondent	85
	Mean	13.84
	Mode	12.00
	Standard deviation	4.67
	Range	19.00
	Minimum	5.00
	Maximum	24.00

To illustrate the findings of the descriptive analysis more clearly, box plots were used. Figure 4.1 shows the box plots, with the minimum value of the score was 5.00, the maximum value of the score was 24.00 and the mean of 13.84. Based on the box plot diagram, the data distribution is almost symmetrically approaching the median value and from here the conclusion that can be made is that the teacher's mastery level of mathematical modelling competency is at a moderate level.

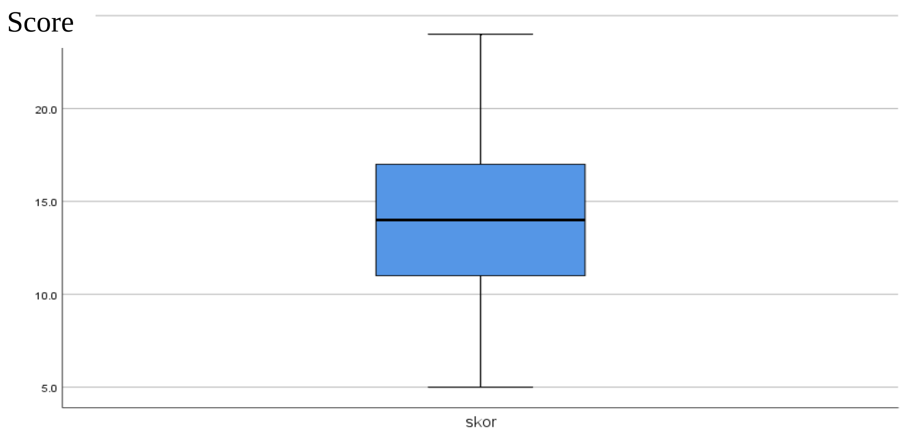

Figure 4.1 Box plot for overall scores of competency test.

Moreover, the frequency table for the mastery level was used to analyze in detail the distribution of respondents' overall scores. Data analysis showed that 43 people or 50.59% of the respondents were at a moderate level of mastery with the range of overall marks obtained was between 11 to 16 marks. These findings indicate that half of the respondents have a moderate level of mastery. In addition, 22 (25.88%) respondents were at a high level of mastery and 2 (2.35%) respondents were at a very high level. For the low level of mastery, the number of respondents is 18 (21.18%) while there is no teacher who is at a very low level of mastery. This indicates that teacher achievement is more inclined towards a high level of mastery rather than low mastery level. In general, it can be concluded that teachers' mastery level in mathematical modelling competency is at a moderate level. The findings of this frequency table are parallel to the box plot results. Table 4.2 shows the details of the frequency table for the mastery level of mathematical modelling competency based on the overall marks obtained by teachers.

Table 4.2 Frequency table for teachers' mastery level of mathematical modelling competency.

	Competency mastery level									
Score interval	**Very high (23 – 28)**		**High (17 – 22)**		**Moderate (11 – 16)**		**Low (5 – 10)**		**Very low (0 – 4)**	
Respondent	Num.	%	Num.	%	Num.	%	Num.	%	Num.	%
85	2	2.35	22	25.88	43	50.59	18	21.18	0	0.00

In addition, the achievement of the respondents also can be seen from the mean score obtained by the respondents. The highest score for the item is 2.00 and the lowest score is 0.00. On average, the mean score obtained by the respondents was 0.99 while the standard deviation was 0.33. The mean value of the score is close to 1.00 which is the intermediate value for the item score. A small standard deviation value indicates a consistent score distribution value and these findings support the standard deviation value for the overall score. Based on the mean value of the overall score and the mean value of the item score, it can be concluded that the respondents' mastery level in mathematical modelling competencies is moderate. Table 4.3 shows the findings for the mean scores of the items.

Table 4.3 Values of mean scores and standard deviations of the items

	N	**Minimum**	**Maximum**	**Mean**	**Standard deviations**
Overall Mean Score	85	0.36	1.71	0.99	0.33

Apart from the analysis that based on the overall score, an analysis on the five sub competencies that have been identified was also conducted. Descriptive analysis according to the sub competencies was conducted to identify the mastery of teachers for each sub competency more specifically. There were five sub competencies measured, which are MMC1, MMC2, MMC3, MMC4 and MMC5. Based on the results of descriptive analysis, the highest mean score is 1.07 for MMC2, followed by mean score 1.06 for MMC4, mean score 0.99 for MMC5, mean score 0.94 for MMC3 and lastly, mean score 0.88 for MMC1. This shows that teachers are more competent in the second stage of the mathematical modelling cycle process, which is to formulate a mathematical model.

The weakness of teachers is in the sub competency of MMC1 which represents the first stage of mathematical modelling cycle process, that is to understand the real problem situation and build a problem model. However, there is a slight difference in the mean score for each sub competency and this indicates that the teachers' mastery from one sub competency to others is not much different. The standard deviation values are 0.49 for MMC1, 0.55 for MMC2, 0.62 for MMC3, 0.70 for MMC4 and 0.61 for MMC5. The values are small which indicates that the distribution of the data is close to the mean value. Table 4.4 and Figure 4.2 show the details of the analysis on the mean scores and standard deviations for the mathematical modelling sub competencies.

Table 4.4 Standard deviation based on five mathematical modelling sub competencies.

	MMC1	MMC2	MMC3	MMC4	MMC5
Standard deviation	0.49	0.55	0.62	0.70	0.61

Figure 4.2 The bar graph represents the mean score based on the five sub competencies of mathematical modelling

Inferential Statistical Analysis

Inferential analysis was conducted to answer the second objective of the research which is to identify the mastery of mathematics modelling competencies among mathematics teachers according to the form level taught in 2021. The respondents of the research consisted of 28 teachers (32.90%) who teach form three students, 26 teachers who teach form four students (30.60%) and 31 teachers who teach form five students (36.50%). Table 4.5 shows the frequency table for the frequency of respondents according to the form level taught.

Table 4.5 Frequency of respondents according to the form level taught.

Form levels taught in 2021	Frequency	Percentage (%)
Form 3	28	32.9
Form 4	26	30.6
Form 5	31	36.5

The inferential analysis performed was a one-way ANOVA. The analysis was conducted to test the set hypotheses which is;

H_o: There is no significant difference between the mean competency test scores based on the form level taught by mathematics teachers in 2021.

H_1: There is significant difference between the mean competency test scores based on the form level taught by mathematics teachers in 2021

Firstly, this research satisfies the statistical assumption of performing a one-way ANOVA analysis. The first assumption is the type of data where the dependent variable is measured in the form of ratio which is the competency test score, while the independent variable is measured in ordinal form which is the form level taught by the mathematics teachers in 2021. The second assumption is independence in observation where each respondent takes part only once in the research and does not affect other participants or groups. The third assumption is that homogeneity for variance is observed, where the Levene Statistic was not significant, which was $F(2,82) = 0.14$, $p = 0.87 > 0.05$. The fourth assumption is where the normality of the data is observed. The results of the normality test for Shapiro - Wilk showed insignificant values for the three form levels taught in 2021, which was $p = 0.73 > 0.05$ for form three teachers, $p = 0.43 > 0.05$ for form four teachers and $p = 0.21 > 0.05$ for form five teachers.

Once the assumptions were met, a one-way analysis of variance (ANOVA) between groups was conducted to examine the mean test scores of teachers who teach form five students compared to teachers who teach form four and form three students. The ANOVA results obtained were not statistically significant, where $F(2, 82) = 1.63$, $p = 0.20 > 0.05$. However, the value of $\eta^2 = 0.0382$ and according to Cohen's (1988), this value indicates a small size effect (Allen et al. 2014). Accordingly, a total of 3.82% variability in competency test scores was associated with the form level taught. Thus, the null hypothesis fails to be rejected, hence there is insufficient evidence to state that there is a difference between the mean competency test scores with the form levels taught by mathematics teachers in 2021. Table 4.6 shows the details of the findings for the one-way ANOVA.

Table 4.6 Result of one-way ANOVA.

		Sum of squares	***df***	**Mean squares**	**F**	**Sig**
Score	Between group	69.73	2	34.87	1.63	0.20
	Within group	1757.96	82	21.44		
	Total	1827.69	84			

Discussion

Based on the analysis of the mathematics modelling competency test, the first objective of the research is to identify the mastery level of mathematics modelling competencies among mathematics teachers. Findings show that the mastery level of mathematical modelling competencies among teachers is at a moderate level. This can be clearly seen from the frequency table where more than half of the respondents (50.59%) are in the moderate category. The mean value of the overall score is 13.84 marks and the mode value of 12.00 marks which is close to the median value, proving that the level of mastery of mathematics teachers in mathematics modelling competencies is at a moderate level. These findings are in line with the findings of a research by Hidayat and Iksan (2018) on prospective teachers in Indonesia. However, when the findings are compared in terms of the mean value of the overall score, the secondary school mathematics teachers obtained better values than the Indonesian prospective teachers.

These findings are likely due to the factors of teaching experience and strong mathematical knowledge possessed by in-service teachers compared to prospective teachers. In-service teachers always apply mathematical knowledge to solve problems in teaching. Therefore, this teaching experience makes in-service teachers have more skills compared to prospective teachers. Hidayat and Iksan (2018) also expressed a similar view in comparing the competency mastery of prospective teachers with the competency mastery of secondary school students implemented by (Frejd and Ärlebäck, 2011).

Moreover, the analysis of competency tests showed that more than half of the teachers obtained overall scores in the moderate category. Not only that, the percentage of teachers who obtained marks in the high category was higher than the low category which was 25.88% compared to 21.18%. In fact, there are teachers who score in very high categories. This indicates a tendency for teachers' mastery levels to increase. This illustration can also be seen in the box plot diagram where the line above the box is longer than the line below the box. Therefore, teachers have the opportunity to enhance their mastery of competencies if they gain more exposure in questions related to mathematical modelling. This is reinforced by a statement by Haines and Crouch (2007) in their research who explained that individual expertise in mathematical modelling can be increased if exposure in solving mathematical modelling problems is given.

In addition to determining the overall mastery level of teachers, teachers' mastery based on competency was also identified. Based on the mathematical modelling cycle process theory by Blum (1996), every stage that needs to be implemented to solve a mathematical modelling problem has a competency that can be mastered. There are five sub competencies assessed in this research and these sub competencies are detailed descriptions of the represented competencies. The findings of the research show that the highest mastery of teachers is in the sub competency of MMC2 which is to detail the problem statement so that it can be formulated into a mathematical model. The next mastery is in MMC4 which is to formulate appropriate mathematical statements in constructing mathematical models. These two sub competencies represent the competency to formulate mathematical models. MMC3 and MMC5 also represent the competency to formulate mathematical models and both are at a moderate level. The mean scores for the four sub competencies are not much different and this shows that the strength of teachers is at the second stage in the process of mathematical modelling cycle.

However, the findings for MMC1 shows that the sub competency is the weakness of teachers. The teacher is less mastered in MMC1 which is to simplify the assumptions by determining the assumptions that will be included and not included in the mathematical model. MMC1 is a sub competency that represents the competency at the first stage in the mathematical cycle process that is to understand the real problem situation and build a problem model. This means that teachers face problems in translating real-life models into mathematical models. These strengths and weaknesses are in contrast with the findings by Hidayat and Iksan (2018) on prospective teachers in Indonesia using the same instrument. Their research showed that prospective teachers in Indonesia mastered the competency in the first stage of the mathematical modelling cycle process and lacked in the second stage of the process.

Nevertheless, these findings are in line with the results of research by Haines and Crouch (2003) on undergraduate students for non-teaching courses and a research by Joo (2017) on three secondary school trainee teachers. The findings of their research showed that undergraduate students and secondary school trainee teachers also experienced problems in the first stage of the mathematical modelling cycle process, which is difficult to relate real-life problems to mathematical models. Various factors can cause these differences to occur and one of them is related to prior knowledge. This is explained by Hidayat and Iksan (2018) in their research where tertiary level students showed better mastery than secondary level students because they have a good mathematical background and they have already taken a mathematical modelling course in the previous semester. Therefore, they have been given exposure and have had basic skills in problem solving involving mathematical modelling.

The findings of the research for the mastery of competencies also showed similar results for secondary school students. Research by Leong and Tan (2020) showed that students' weaknesses in mathematical modelling competencies were in the early stages of the cycle, while research by Frejd and Ärlebäck (2011) showed similar findings but their respondents were able to formulate problems and determine variables, parameters and constants for mathematical models. This is because they have been exposed to the skills of constructing mathematical models in their school syllabus. This explains that mastery in mathematical modelling competencies depends on students' prior knowledge that they have learned while in the classroom. Thus, compared to the in-service teachers, the teachers have stronger prior knowledge and good mathematical background than students and pre-services teachers. In-service teachers always practice their mathematical knowledge in teaching but have lack exposure in solving mathematical modelling problems. This statement is reinforced by the research of Haines and Crouch (2007) which concluded that the development of the level of expertise or mastery in mathematical modelling increases as existing knowledge and exposure to mathematical modelling questions increases. This also may be the reason for the mastery level of in-service teachers is at a moderate level even though they have strong prior existing knowledge as they are given less exposure to mathematical modelling questions.

These differences of mastery in mathematical modelling competencies can be due to the type of instrument used. Past studies that used problem-solving questions of mathematical modelling provide more detailed indication than competency tests. However, researchers are of the same opinion that factors of exposure, experience and existing mathematical knowledge can cause differences in the mastery level of mathematical modelling competencies. This explains the differences in the mastery of competencies for students, university students, trainee teachers and in-service teachers. According to Maaß (2006), mathematical modelling competencies consist of the skills and ability to implement the modelling cycle process correctly and have the willingness to implement it. Therefore, these factors are part of the readiness in implementing the mathematical modelling cycle process.

In addition, the findings of one-way ANOVA failed to reject the null hypothesis, where there is no significant difference between the mean scores of competency tests with the form levels taught by mathematics teachers in 2021. This indicates that the available evidence is insufficient to state that there is a difference between the mean scores. In general, there is no difference in mastery of mathematical modelling competencies between form five teachers compared to form four and form three teachers. This is likely because these form five, form four and form three teachers have lack knowledge and exposure in solving mathematical modelling problems so there is not much difference in their competency test scores. The teachers answered the test based on their existing mathematical knowledge, skills and experience in general mathematical problem solving.

Implications

The findings of this research have implications from the point of view of educational practice and theory. From the point of view of educational practice, the results of the research help to identify the strengths and weaknesses of the teachers in mathematical modelling. Teachers' strengths are at the second stage of the mathematical modelling cycle process and teachers' weaknesses are at the first stage of the cycle process. Knowledge of this information can help teachers to overcome their weaknesses and improve their abilities. For example, teachers can overcome their weaknesses by carrying out a mentoring program with teachers who have skills in translating real-life problems into mathematical models. Furthermore, the difficulty in mastering the topic of mathematical modelling causes teachers to have skills to deliver their lessons effectively. Therefore, knowledge of the strengths and weaknesses of teachers can help the authority to design appropriate programs and workshops for teachers. Such programs that can improve teachers' skills in solving mathematical modelling problems will give teachers more exposure and this in turn can improve teachers' abilities. Teachers who are skilled in mathematical modelling will create effective learning and teaching processes. As a result, students will be able to master the topic and thus, the goals to produce teachers and students who have a high level of mastery in mathematical modelling can be achieved.

In addition, the results of the teacher's mastery can provide an overview to the Ministry of Education (MOE) on the readiness of teachers to teach the topic of mathematical modelling. As this topic has just been introduced, information on teacher readiness can help the MOE to design appropriate intervention programs to enhance teachers' capabilities. The authorities have the facilities in terms of finance, infrastructure and experts to assist teachers. In addition, the MOE can also use the knowledge of the mastery and readiness of these teachers to evaluate the content and exercises provided in the textbook. This can help the MOE to improve the syllabus in line with the ability of teachers and students.

The implications of this research can also be seen from a theoretical point of view. Compared to other countries in Europe, the topic of mathematical modelling is still less discussed in Malaysia. Research related to mathematical modelling in education is still limited. In addition, research involving teachers and students in schools was less than students in universities. This is likely because students are exposed to the topic of mathematical modelling while at university in preparation for the working field. Therefore, this research is expected to provide contributions and ideas for more research in the field of education, especially in Malaysia.

Suggestions for Further Research

There are several suggestions for further research that can be implemented in the future. The first suggestion is to identify the factors that influence the mastery of mathematical modelling competencies. Based on previous research that involves determination of mastery level among school students, university students or teachers, factors such as exposure, experience and existing mathematical knowledge indirectly affect the mastery of individual competencies. Therefore, a specific research to prove these factors and the extent to which they affect individual mastery can be executed.

Second suggestion is a research for other competencies in the mathematical modelling cycle process, especially those involving problem-solving measures can be applied since the use of mathematical modelling competency tests is limited to items that could test individual knowledge directly without involving problem -solving measures. Studies involving computational measures will provide a more accurate assessment of the mastery level in mathematical modelling competencies as well as the details strengths and weaknesses. Moreover, the continuity of this research by identifying teachers' mastery of competencies involving the third to seventh stages in the mathematical modelling cycle process will complete this research. Research to identify the ability of in-service teachers in mathematical modelling cycle process such as to solve constructed mathematical models, interpret solutions, evaluate and verify solution steps made and refine models are still limited in Malaysia.

Finally, a research of secondary school teachers using the same instrument for the period after the next five years could be implemented to assess the improvement of teachers' mastery. Based on the research of Haines and Crouch (2007), expertise or mastery in mathematical modelling will increase when more exposure is given in solving mathematical modelling questions. Therefore, a follow-up research can prove whether the mastery level of secondary school teachers in Selangor has increased to a better level or vice versa. Furthermore, the research conducted can test whether there is a difference in mastery for teachers who teach the form five students compared to form four and form three teachers. This is because the teacher has been given more exposure therefore the knowledge will become stronger and the experience of solving the questions will also be better. Hence, further research should be conducted to see the differences in the mastery of mathematical modelling competencies for in-service mathematics teachers.

Conclusion

In conclusion, the mastery level of mathematics teachers in Selangor in mathematics modeling competencies is at a moderate level. Mastery based on five sub competencies indicates that teachers competent in four sub competencies that represent the second stage in the mathematical modeling cycle process. In contrast, teachers are lack competent in the first stage of the mathematical modeling cycle process represented by the first sub competency. In addition, there is no difference in mastery for teachers who teach form three, form four and form five students in 2021. There are three factors that are likely to be factors in this finding, which were the exposure, experience and existing mathematical knowledge among teachers.

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